SPECTRAL TUNING

Eric Lyon

Music Department and Electro-Acoustic Graduate Program, Dartmouth College
eric.lyon@dartmouth.edu

Abstract

Spectral tuning is a sound processing method based on the phase vocoder. In this method, most or all partials are tuned to a fixed set of frequency values corresponding to a desired scale. If the input sound is a monophonic melody, the result is a kind of auto-tuning, providing greater flexibility in tuning schemas than with commercial auto-tuning programs. When applied to polyphonic or textural sounds, the process can generate more complex effects. This paper will discuss the method, its implementation as a real-time processor, and some musical applications by the author.

1 Introduction

Spectral tuning is a form of cross synthesis where the frequency content of an input sound is replaced with that of an abstract frequency grid, more commonly known as a scale. Although we will discuss fixed scales exclusively, the technique is completely compatible with algorithmically controlled evolving scales as discussed in e.g. (Moore 1990). The signal processing method is straightforward. The input sound is analyzed in overlapping windows, transformed with a short time Fourier transform (STFT), and successive phases are unwrapped, yielding an instantaneous estimate of frequency in each analysis bin. The process described so far is just the phase vocoder as described in (Dolson 1986). A simple added twist implements the spectral tuning. A scale is provided as a list of frequency values between zero and the Nyquist frequency. For each analysis bin, the instantaneous estimated frequency is quantized to the nearest frequency value found in the scale frequency list. The tuned spectrum is then resynthesized with an oscillator bank.

2 Musical Effects of Spectral Tuning

The effects of spectral tuning depend critically on two components, the scale and the input sound. Scales with familiar profiles impose their harmonic structure in immediately recognizable form. However, unusual scales, those with unequally spaced steps, or relatively few components have a different perceptual effect, more timbre-related than harmonic. Input sounds that are complex, noisy or inharmonic maintain their temporal features but also continuously articulate the scale as a unified structure. White noise provides the extreme example of this effect. Sounds with harmonic spectra that exhibit tonal structure, whether melodic or polyphonic enter into a complex interaction with the tuning scale. With monophonic sounds, the perceived fundamental of each note is forced to the nearest available frequency in the scale. This effect can sound similar to auto-tuning or instances of vocoding where one of the vocoder sources is itself a tuned melody, such as in Cher's hit song "Believe" (Cher 1998). For polyphonic tonal input, the result of spectral tuning can be the somewhat startling effect of changing the mode of the composition, which remains otherwise recognizable. A piece in a minor key can be automatically transformed to major mode. One interesting experiment was to map a mariachi tune to harmonic minor, resulting in a kind of mariachi-klezmer tune. In many cases there is a somewhat artificial aspect to the resynthesized sound, due to the tuning of the upper partials. This can be ameliorated by either adding more scale degrees to higher octaves or by not tuning the upper partials.

3 A Live Implemenation In Max/MSP

A Max/MSP external was developed using the FFTease framework (Lyon and Penrose 2000) to experiment with spectral tuning in a live context. A screenshot is given in Figure 1. A number of scales are preprogrammed into the external, such as major, minor, slendro, eq12, eq8, etc. In addition arbitrary scales may be introduced as a list of numbers. Of special interest is the "toptune" message, which specifies the highest of the synthesized partials to retune. Manipulating this parameter live creates a striking effect as the sound gradually morphs from its original to its retuned form. The pvtuner~ external yields attractive performance options centered on manipulating the base frequency, effectively sliding the tuning grid up and down. Manipulating this parameter by keyboard, one can perform "scale melodies".

Resynthesis is by oscillator bank. To reduce the computation load, a maximum frequency to synthesize may be specified; all higher frequency oscillators are turned off.

A synthesis threshold is provided, such that bins with very low amplitude may also be omitted from the computation. Given the oscillator bank resynthesis method, global transposition (frequency scaling) was provided at negligible CPU cost. The external pvtuner~ was first used for live performance in the author's Max/MSP piece *Second Skin* (Lyon 2002).

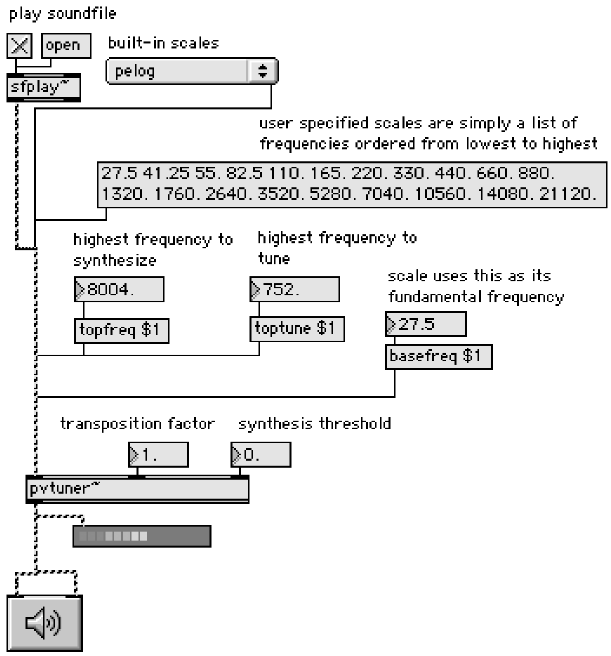

Figure 1. A Max/MSP patch implementing spectral tuning using an external created by the author.

4 First Compositional Use

I developed the technique of spectral tuning in 2000 and used it in my computer music composition *Sacred Amnesia* (Lyon 2001). The programmatic concept for this composition was based on the process of ideological history formation, where a pre-determined narrative is imposed on facts that become increasingly plastic, appearing or disappearing as convenient, sometimes interpreted to mean the opposite of what they might once have signified. This process seemed to me closely related to traditional models of musical transformation and discourse. Two sections in particular employed spectral tuning to create specific musical and dramatic effects by transforming historical events.

The first section used a segment from Richard Nixon's popular "I Am Not a Crook" speech (Nixon 1994 [1973]), discussing the source of questioned personal funds. This segment was tuned to a major scale. The result was to give an angelic halo to Nixon's voice, enhancing the quality of self-righteousness in Nixon's delivery and emphasizing the integrity of Nixon's personal finances. Although intelligibility was somewhat impaired, the characteristic timbre of Nixon's voice is recognizable, and all the words are perceptible after a few listenings.

The second section was inspired by a quip from Brian Ferneyhough (Ferneyhough 1990) in which he suggested that we are no longer living in "history" but rather in individual "histories", and that it was perfectly sensible for a composer in the late 20th century to compose as if Arnold Schoenberg had never invented the 12-tone method of composition. I extracted the opening of *Mondestrunken*, the first movement from Arnold Schoenberg's pre-12-tone atonal composition *Pierrot Lunaire* (Schoenberg 1914 [1912]) and tuned it to a major key. The result can be rather disconcerting to listeners who are familiar with Schoenberg's dark, disturbing work. The retuned version, by contrast has an innocent, whimsical quality, more than a bit suggestive of the style of Aaron Copland (Lyon 2001a).

5 Future Enhancements

Although at its best, processing with spectral tuning creates dramatic and unique results, in less successful cases there can be extreme "bubbling" artifacts, due to energy in adjacent frames vacillating between adjacent bins. Enough of this motion can seriously degrade the resulting sound. A possible solution is to stabilize the strongest partials through partial tracking. Another possibility is to make the scale itself adaptive, adjusting itself to pitch curve perturbations.

6 Conclusions

Spectral tuning is a useful compositional signal-processing tool. The technique provides the ability to gain precise control over the frequency content of any sound and impose new, coherent frequency structures upon it. There is increasing interest in the computer music community in controlling pitch aspects of timbre-focused music, and spectral tuning provides an appropriate tool for exploring this musical direction.

References

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